INSTRUCTION BOOK

for

MODEL FM-3 SERIES

VHF FREQUENCY METERS

Gertsch PRODUCTS, INC.

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3211 South La Cienega Boulevard, Los Angeles 16, California • TExas 0-2761 - VErmont 9-2201

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Gertsch Products, Inc. guarantees any equipment which we manufacture to meet the advertised performance specifications applying to that particular equipment.

Gertsch Products, Inc. warrants each instrument of its manufacture to be free from defects in material and workmanship. Our obligation under this Warranty is limited to servicing or adjusting any instrument returned to our factory for that purpose, and to making good at our factory any part or parts thereof except tubes, fuses or batteries which shall, within one year after making delivery to the original purchaser, be returned to us with transportation charges prepaid, and which on our examination shall disclose to our satisfaction to have been thus defective.

Gertsch Products, Inc. reserves the right to make changes in design at any time without incurring any obligation to install same on units previously purchased.

This Warranty is expressly in lieu of all other obligations or liabilities on the part of Gertsch Products, Inc., and Gertsch Products, Inc. neither assumes nor authorizes any other person to assume for them any other liability in connection with the sales of Gertsch Products, Inc. instruments.

This Warranty applies only to the original purchaser unless approval for resale is obtained in writing from Gertsch Products, Inc.

Equipment _____

Serial No. _____

Sold to _____

Date Sold _____

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SECTION I
GENERAL DESCRIPTION

All GERTSCH Frequency Meters are based upon a new, patented system of circuitry including the combination of a Crystal, High Frequency and Low Frequency Oscillators, providing unusual accuracy and stability heretofore impossible in a portable instrument.

1. PURPOSE OF INSTRUCTION BOOK.

This Instruction Book describes the Models FM-3 FM-3R, and FM-3/PS-3 Direct Reading VHF Frequency Meters. Information concerning Description, Operation, Adjustment, Maintenance and Parts List is also included.

2. VARIOUS TYPES OF MODEL FM-3.

The Model FM-3 chassis forms the basic unit of the three types of Frequency Meters which are as follows:

A. The Model FM-3. This includes the basic unit mounted in a portable carrying case with provisions in the lower part of the case for one set of dry cell batteries and with plug and switch connections so arranged that an external regulated power supply can be used with the equipment.

This assembly permits the use of the instrument as a portable battery operated device for field use and as a laboratory device when used with external power supply.

B. The Model FM-3R. This unit consists of the basic FM-3 unit along with a regulated power supply, Model PS-3, mounted on a common 8-3/4 x 19 inch rack panel.

This assembly is intended for a fixed station use where permanent installation is desired.

C. FM-3/PS-3. This model consists of a basic FM-3 unit mounted in a carrying case (same as FM-3) but with a standard PS-3 power supply mounted in the lower compartment of the case, thus providing a portable instrument which will operate from 105 - 125 volts, 50 - 60 cycle, or 230 volts, 60 cycle power source (export only).

D. FM-3/PS-3C. This model consists of the basic FM-3 unit mounted in a carrying case with an external PS-3C power supply and a change over switch to allow the unit to operate from battery or a. c.

E. The Model FM-3R is also supplied, on special request, mounted in a metal cabinet.

3. FUNCTION OF EQUIPMENT.

The Model FM-3 series are used to accurately measure or generate any frequency within the range of 20 - 1000 mc. with the performances noted in the performance characteristics table.

The Model FM-3 Series can be used as a signal generator. However, it must be kept in mind that the leakage from the instrument may be high, and the output cannot be controlled and is not known precisely.

The unusual performance of this equipment is due primarily to the incorporation of such circuit features as the multiple-oscillator method of frequency measurement and generation, as well as the "lock in" circuit. Further details on these features are included under Section III, Theory of Operation - Locking Buffer.

4. EQUIPMENT SUPPLIED.

As shipped, the various models of the FM-3 are supplied with the following equipment. (Additional equipment required for complete operation is indicated in caps in each model.)

A. Model FM-3.

(1) The FM-3 unit is mounted in a carrying type case complete with antenna, instruction book, correction curve, and instruction chart.

(2) Additional Equipment Required.

(a) 1 SET OF BATTERIES CONSISTING OF 3 BURGESS M30, OR EQUIVALENT, 45 VOLT "B" BATTERIES. 3 BURGESS 2F4, OR EQUIVALENT, 6 VOLT "A" BATTERIES. NOTE: For details of installation, see figure 10 (and refer to Section IV, Maintenance, paragraph 6).

(b) 1 SET OF HEAD PHONES. As shipped, the FM-3 series are connected for use with 600 - 2000 ohm magnetic phones (impedance is not critical). Can also be used with high impedance crystal phones. For information regarding conversion to use high impedance crystal phones, see Section IV, Maintenance, paragraph 7.

B. Model FM-3R.

(1) The basic FM-3 unit combined with Model PS-3 Regulated Power Supply, mounted on an 8-3/4 x 19 inch rack panel, including power cord, antenna, correction curve, instruction book, and operating instruction chart.

(2) Additional Equipment Required.

(a) 1 SET OF HEAD PHONES, SAME AS FM-3.

C. Model FM-3/PS-3.

(1) The basic FM-3 unit in carrying case with PS-3 mounted in lower portion. Complete with power cord, instruction book, correction curve, operating instruction chart, etc.

Accuracy:

With Constant Temperature, 20° to 30°C: ±.001%
With Variable Temperature, -15° to +55°C: ±.0025%

Stability:

Long Term, Constant Temperature: ±.002%
Short Term, Constant Temperature: ±.001%

Frequency Resetability:

Any Constant Temperature: ±.0005%

Auxiliary Output Frequencies:

1.0 through 20 mc. each point, ±.0005% at 25°C
1 - 2 mc. ±.02% -15 to +55°C

Modulation:

30% at 1000 cycles (can be switched in or out).

FREQUENCY RANGE:

20 - 1000 mc. Can also be used below 20 MC AS A MEASURING DEVICE ONLY, by measuring a harmonic of the unknown signal and dividing by the proper factor. For example: a 5 mc. signal would be measured at 20 mc. (4th harmonic), at 25 mc. (5th harmonic) etc.

NOTE: Greater low frequency range is possible under certain conditions. For details see Section II, Operation and Adjustment, paragraph 6.

SENSITIVITY:

10 millivolts over 20 - 1000 mc. band for 1 milliwatt audio output (across 600 ohms) connected for low impedance.

RF OUTPUT:

1 millivolt over entire band.

RF OUTPUT IMPEDANCE:

Approximately 50 ohms, above 100 mc. It is essentially matched.

AUXILIARY OUTPUT:

High impedance.

INPUT-OUTPUT JACK SOURCE IMPEDANCE:

50 ohm in series with 100 mmf.

AUXILIARY OUTPUT JACK SOURCE IMPEDANCE:

25 mmf.

(2) Equipment Not Supplied.

(a) 1 SET OF HEAD PHONES, SAME AS FM-3.

5. POWER CONSUMPTION.

A. The Model FM-3 (Battery Operated). WHEN USED WITH THE RECOMMENDED BATTERIES, THE MODEL FM-3 HAS A BATTERY LIFE OF 5 HOURS CONTINUOUS DUTY AND 8 HOURS INTERMITTENT DUTY.

When used with an external power supply (other than the PS-3) the following currents and voltages are required:

(1) Plate supply 135 volts at .032 amps, regulated. (See Section III, Theory of Operation - Power Supply.)

(2) Filament supply 6.3 volts at 1.2 amps. Regulation is not required unless the voltage varies greater than 5.7 - 6.9 volts. (For recommended Regulated Power Supply, other than PS-3, see figure 8.)

B. The Model FM-3R requires a power source of 105 - 125 volts, 50 - 60 cycles. Total volt-ampere consumption is 37 VA.

Provision has been made on the primary circuit of the power transformer to allow for operation at 230 volts, 60 cycle.

6. DESCRIPTION OF EQUIPMENT.

The FM-3 series consist basically of 9 major circuits, that is, Search Oscillator, HF Detector, Audio Amplifier, Buffer, Balanced Modulator, Calibration Detector, Crystal Harmonic Multiplier, LF Oscillator and Crystal Oscillator. A block diagram of the basic circuits is shown in figure 4.

The Frequency Meter is mounted in an aluminum case with a removable hinged door. The upper portion of the case contains the Frequency Meter unit while the lower portion contains either batteries or Regulated Power Supply, depending upon the model number. The correction chart is mounted on the door along with the operating instruction chart.

7. DIMENSIONS AND WEIGHTS.

A. Model FM-3: Width, 11 inches. Depth, 9-1/2 inches. Height, 14 inches. Weight, 32 pounds (including batteries) and 18.25 pounds (less batteries).

B. Model FM-3R: Width, 19 inches. Depth (overall), 9-1/8 inches. Height, 8-3/4 inches. Weight, 18 pounds.

C. Model FM-3/PS-3: Dimensions same as FM-3. Weight, 22 pounds.

D. Model FM-3R (installed in cabinet): Width, 23-1/2 inches. Depth, 10 inches. Height, 10-3/4 inches. Weight, 26 pounds.

SECTION II
OPERATION AND ADJUSTMENT

1. FUNCTION OF EQUIPMENT.

The models FM-3 series direct reading VHF Frequency Meter will measure or generate any frequency within the range of 20 - 1000 mc. with a minimum accuracy of .0025%. They can also be used below 20 mc. as described in this section.

2. READING THE DIALS.

In the model FM-3 series the frequency is read directly on the dials. The left hand dial (high frequency oscillator) is calibrated in megacycles and the center and right hand dial is calibrated in fractions of a megacycle. For example, see figures 1 and 2. The small dial (MC selector) is also calibrated in megacycles. These four dials all operate in such a manner that the frequency is read directly over the fundamental range of the Frequency Meter which is 20 - 40 mc. It is very important that the dial readings correlate with each other. For example, if the instrument is set to 23.999 mc. the left hand dial must be very close to 24 mc., the center and right hand dials should read .999 and the MC selector dial should read 23. This is the only correct combination to obtain this instrument frequency. It may be possible that the frequency of the high frequency oscillator does not exactly agree with the dial calibration so that in the previous example the left hand dial might possibly read over 24 mc., but the instrument reading will still be correct if attention is paid to the reading as a whole. In this case, it obviously cannot be 24.999 mc. since the high frequency oscillator dial is very close to 24 mc. and the low frequency dials read .999 and the MC selector dial reads 23. Therefore, all dial readings must correlate with each other.

It must be kept in mind at all times that the Frequency Meter is a harmonic device with a fundamental range of 20 - 40 mc. and the readings taken from the dials are the fundamental frequency readings and must be multiplied or divided by the proper integer, this integer being the harmonic used. For example, if the frequency to be measured is within the range of 20 - 40 mc. multiply by one. In other words, the dial readings are the frequency measured. If the frequency to be measured

is within a range of 40 - 80 mc., multiply by two, and so on. The appropriate multiplication factor to be used for each frequency is listed on the low frequency oscillator dial readings correction chart which is mounted on the cover of the instrument in the case of the FM-3 and adjacent to the meter in the case of the FM-3R.

In the case of generation of frequencies, the frequency to be generated must be divided by the appropriate integer to obtain the Instrument Frequency. For example, if the frequency to be generated is within the range of 40 - 80 mc. this frequency would be divided by two and the result is the desired Instrument Frequency which would be set up on the Frequency Meter.

3. USE OF THE CORRECTION CURVE.

The low frequency oscillator dial readings correction curve is located, in the case of the FM-3, on the cover of the instrument. In the case of the FM-3R the low frequency oscillator dial readings correction curve is located to the left of the instrument on the main panel. This curve gives the correction to be added or subtracted from the center and right hand dial readings as a function of the dial readings. The sample curve is shown in figure 3. Assuming an instrument reading of 23.5572 mc. the center and right hand dials would read .5572. Locating the .5572 on the correction chart, it is seen that there is to be a correction of .0007 to be added to the dial readings resulting in a corrected dial reading of .5579, resulting in a corrected instrument reading of 23.5579 mc. The curve is used in a converse manner when generating a frequency. Assuming it is desired to generate 23.5579 mc. or any of its harmonics, the .5579 is located on the correction curve and it is seen that .0007 is to be added to the dial readings. Therefore, the dials must be set so that they read .5572. Therefore, it is obvious that in generating a frequency the curve is used in exactly a converse manner from its use in measuring a frequency.

THE MODEL FM-3 SERIES IS PROVIDED WITH A DUAL LUBBER LINE TO ELIMINATE PARALLAX. WHEN READING THE INSTRUMENT ALWAYS SIGHT INTO THE DIALS IN SUCH A MANNER THAT BOTH LUBBER LINES ARE ALIGNED.

4. METHOD OF OPERATION.

A. To Measure a Frequency.

(1) Place the Power Switch in the ON position. Allow at least a fifteen minute warm up period. If the ambient temperature has been suddenly changed due to transportation or any other reason, allow the instrument to stabilize at the new ambient temperature for a period of at least an hour before turning it on. Plug the phones in the phone jack and provide suitable coupling to the source being measured.

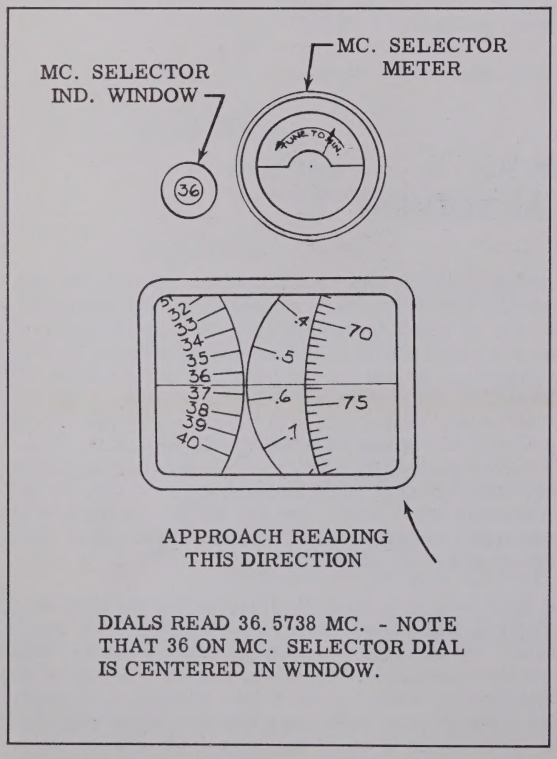

Figure 1. FM-3 Sample Dial Reading

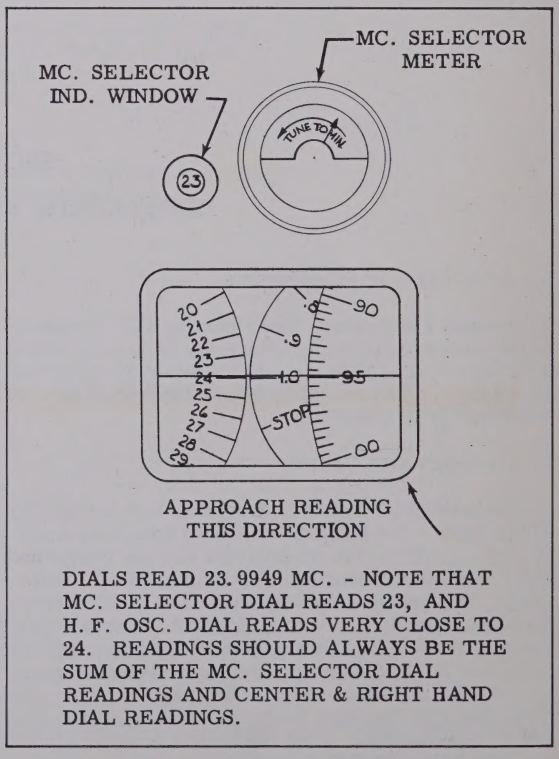

Figure 2. FM-3 Sample Dial Reading

(2) Place the Function Switch in the BEAT position.

(3) Locate frequency to be measured by tuning the HF oscillator knob (A) in the vicinity of the expected frequency as indicated on the left hand dial until a beat note is heard. Tune to zero beat. It is not necessary to precisely zero beat at this point.

(4) Place the Function Switch in the READ position.

(5) Turn the MC selector knob (B) until the number that appears in the window adjacent to the knob agrees with the left hand dial reading in the main window. (For example, left hand dial reads between 36 and 37 mc., MC selector should be tuned so that 36 appears in the small window.) Adjust the MC selector knob (B) for minimum meter reading.

(6) Tune the LF oscillator knob (C) in that vicinity where the right hand dial readings agree with the fractional part of a megacycle as indicated by the left hand dial reading. (For example, left hand dial reads approximately 36.7, right hand dials should be tuned in the vicinity of .7.) Tune until beat note changes pitch drastically and the signals are heard to lock. As the "lock-in" is approached the beat note will become very ragged sounding and as the lock occurs there will be a definite squawk, and if any beat notes are heard, they will be very pure. Continue tuning until zero beat against the unknown signal is reached. At this point check for proper settings and "lock-in" by detuning the HF oscillator knob (A) slightly in either direction and noting that for slight detunings, conditions as heard in the phones remain unchanged.

(7) Read all dials to check correlation of dial readings. If the dial readings do not correlate, follow procedure outlined in paragraph 5.

(8) Read the right hand dials and calibrate according to paragraph 4C (Calibration).

(9) After calibration, place the Function Switch in the READ position and repeat step 6 and carefully zero beat.

(10) Read the dials.

(11) Apply the correction factor from the correction chart.

(12) Multiply the corrected dial readings by the appropriate multiplication factor from the correction chart. The result is the frequency of the source being measured.

B. To Generate a Frequency.

(1) Same as paragraph 4A, step 1.

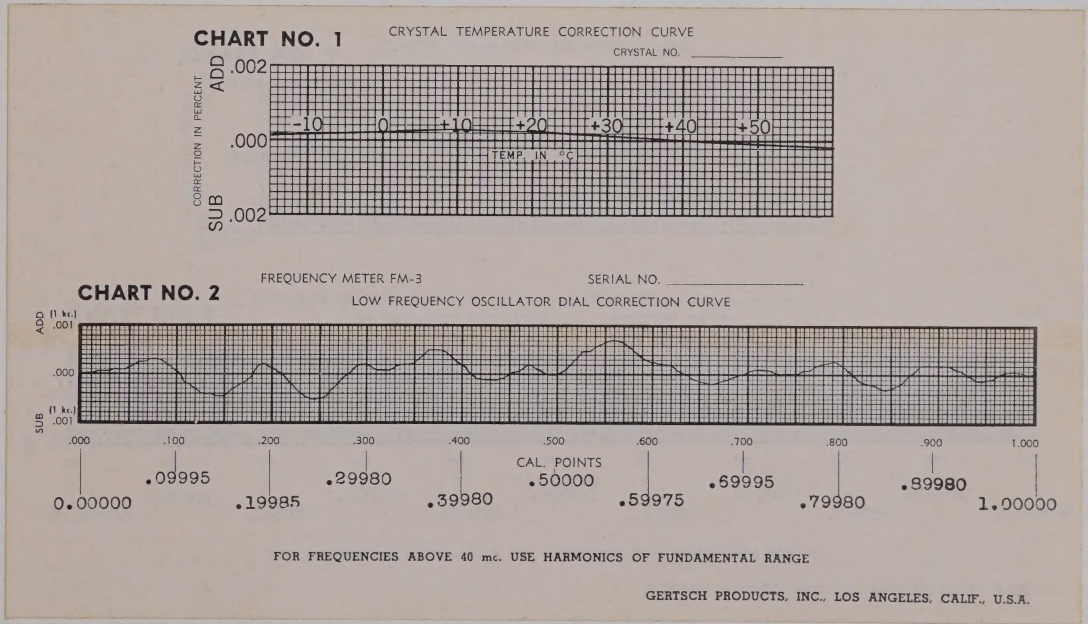
CHART NO. 1
CRYSTAL TEMPERATURE CORRECTION CURVE
CRYSTAL NO. _____
CORRECTION IN PERCENT
ADD .002
.000
SUB .002
-10 0 +10 +20 +30 +40 +50
TEMP IN °C
FREQUENCY METER FM-3
SERIAL NO. _____
CHART NO. 2
LOW FREQUENCY OSCILLATOR DIAL CORRECTION CURVE
ADD (1 kc.) .001
.000
SUB (1 kc.) .001
.000 .100 .200 .300 .400 .500 .600 .700 .800 .900 1.000
CAL. POINTS
0.00000 .09995 .19985 .29980 .39980 .50000 .59975 .69995 .79980 .89980 1.00000
FOR FREQUENCIES ABOVE 40 mc. USE HARMONICS OF FUNDAMENTAL RANGE
GERTSCH PRODUCTS, INC., LOS ANGELES, CALIF., U.S.A.

Figure 3. Sample Correction Curve

(2) Divide the desired frequency by the appropriate factor obtained from the correction chart to obtain the Instrument Frequency. For example, to generate 84 mc. the appropriate factor from the chart is 4, therefore the Instrument Frequency would be 84 divided by 4, or 21 mc.

(3) Calibrate according to paragraph 4C (Calibration).

(4) Place the Function Switch in the READ position.

(5) Tune the low frequency ostillator knob (C) so that the right hand dials read the fractional part of the instrument frequency after the correction factor from the correction chart has been applied. For example, if the desired Instrument Frequency is 23.5579 then .5579 is located on the correction chart and it is seen that .0007 is to be added to the dial readings. Therefore, the dials must be set so they read .5572.

(6) Tune MC selector (B) so that the megacycle portion of the Instrument Frequency appears in the window adjacent to the knob. Adjust for minimum meter reading.

(7) Tune the HF oscillator knob (A) in the vicinity of the desired Instrument Frequency as indicated on the left hand dial until it is heard to lock. Adjust to the center of the lock-in range.

(8) The desired output frequency is now available at the input-output jack. If modulated output is desired, place the Function Switch in the MOD position.

C. Calibration

(1) Place the Function Switch in the CAL position.

(2) From the correction chart select the CAL point nearest to either the right hand dial reading obtained in paragraph 4A (To Measure a Frequency), step (6), or to the fractional part of a megacycle of the Instrument Frequency obtained in paragraph 4B (To Generate a Frequency), step (2). ALWAYS USE THE CALIBRATION POINT CLOSEST TO THE OPERATING POINT.

(3) Set the right hand dials by tuning the LF oscillator knob (C) so that their reading is the selected calibration point. Adjust the calibration knob (D) for zero beat. The calibration knob should point very close to the center mark on its scale for all calibration points.

D. Methods of Coupling.

The method of coupling to the Frequency Meter depends upon the type of source being measured as well as the relative output of the source being measured. In the case of a signal from a transmitter or oscillator, sufficient coupling will be obtained in most cases with the antenna plugged into the Frequency Meter and using the near radiation field from the transmitter. For signal generators and other weak signal devices, direct coupling to the input-output jack via a matched coaxial line is recommended. In this manner signals may be measured throughout the entire frequency range whose voltage magnitude is at least 1000 microvolts. In the case of signals considerably weaker than this the use of an auxiliary receiver to obtain the measurement is recommended. In this case the procedure will be as follows:

(1) Locate the frequency to be measured on the receiver.

(2) Provide suitable coupling between the receiver and the Frequency Meter.

(3) Tune the search oscillator until a beat note is heard in the receiver.

(4) Change the receiver tuning slightly and note whether or not the beat note frequency changes. If the beat note frequency changes the response is an image response or a response with a local ostillator harmonic or other type of spurious receiver response. If this is the case, continue tuning the high frequency search oscillator until a proper response is obtained, that is, one in which the beat note frequency does not vary for slight receiver tuning changes.

(5) Use the head phones on the Frequency Meter and with the Function Switch in the READ position, proceed as in paragraph 4A, step (6), until the lock-in condition has been reached. Continue tuning the low frequency oscillator dial until the locked search oscillator reaches zero beat with the signal being measured, as indicated in the receiver.

With this procedure it is possible to measure the frequency of a remote source.

E. Possible Spurious Responses.

It is possible in certain cases to obtain a false reading due to spurious signals or non-correlated dial readings. Details will now be taken up on this subject.

(1) Errors due to non-correlated dial readings. It is possible when very close to integral megacycle points of the Instrument Frequency to obtain a false reading due to a non-correlated set of dial readings. This can occur only when the combined readings of the right hand dials and the megacycle selector indicate a frequency approximately 1 mc. higher than the left hand dial. For example, it is possible to obtain a lock-in condition and a frequency measurement with the left hand dial reading very close to 23, the MC selector reading 23 and the right hand dials reading 1.000. Another indication of this error is the width of the lock-in range. It will be considerably narrower than normal.

(2) Improper readings due to spurious responses. As the high frequency end of the Instrument Frequency is approached, there will be an increase in the intensity of the spurious responses due to decreasing selectivity in some of the tuned circuits and increased leakage through the balanced modulator. These spurious responses occur when the Function Switch is in the READ position and the right hand dials are very close to the calibration points listed on the correction chart. If the frequency being measured happens to fall very close to these dial readings, some difficulty may be experienced in distinguishing between the frequency

being measured and the spurious responses. Several methods can be used to unambiguously determine the proper response.

(a) In a case where the frequency being measured is very close to the spurious response, zero beat one of the beat notes very carefully, then turn off the unknown signal. If the remaining beat note does not disappear when the signal is turned off, the response is the correct one. If the remaining beat note does disappear the response is false and the other zero beat is the proper one.

(b) If the unknown frequency is not too close to the spurious response, the proper zero beat can be ascertained from the fact that the spurious responses always occur at the listed calibration points.

F. Additional Notes on Operation.

(1) The width of the lock-in range as measured on the right hand dials should always be at least 15 kc. Range is greatest at HF end.

(2) Proper measurements and output frequencies will be obtained when and only when the instrument is in the "lock-in" condition.

(3) Right hand dial readings should always be approached in the direction indicated by the engraved arrow on the panel. This excludes the possible error due to backlash in the gear train.

(4) For maximum accuracy, always use the aligned double lubber line method of eliminating parallax and read the dials to the closest 50 cycles.

5. USE OF THE TEMPERATURE CORRECTION CURVE.

The Instrument Frequency is directly proportional, to the first approximation, to the crystal frequency. For this reason a chart has been included which gives the correction of the crystal frequency in fractions of a per cent as a function of crystal temperature. If these corrections are taken into account, the Instrument Frequency and therefore all measured or generated frequencies, can be corrected for crystal frequency errors due to changes in crystal temperature. The chart is located at the bottom of the Operating Instruction Chart in the cover of the instrument.

Use of the thermometer. A thermometer has been supplied which measures the temperature of the 1 mc. crystal. This thermometer may be read by unscrewing the knurled aluminum cap on the front panel to the right of the Function Switch.

The thermometer must be removed fairly rapidly in order that its reading will not drop. The temperature read from the thermometer is the crystal temperature and is to be used when applying the temperature correction from the Temperature Correction Chart.

When the Frequency Meter is adjusted at the factory, the crossover point on the chart is drawn for an external ambient temperature of 25°C. If the instrument is to be used constantly in a temperature differing considerably from 25°C., it may be desirable to rest the crystal trimmer. This may be accomplished by following the procedure outlined in Section IV, paragraph 1. When this is done the thermometer should be read and a new curve drawn so that the zero correction point occurs at this temperature.

A. Correction for Frequency Measurements.

The frequency is measured according to Section II, paragraph 4A (To Measure a Frequency). Finding the crystal temperature at which the measurement was taken on the chart, the correction factor is noted. Multiply the indicated frequency obtained by this correction factor and add or subtract, as indicated by the chart, the above result to the indicated frequency.

B. Use in Generating Frequency.

Find the Instrument Frequency as described in Section II, paragraph 4B (To Generate a Frequency). Locate the crystal temperature at which the generation is to be made and note the correction factor for this crystal temperature. Multiply the desired Instrument Frequency by this correction factor and add or subtract, conversely to the manner indicated on the chart, the value obtained to the desired Instrument Frequency. This result is the temperature corrected Instrument Frequency which is to be set up to obtain the desired output frequency.

6. USE AT LOWER FREQUENCIES.

The Frequency Meter may be used for measuring frequencies below 20 mc. The only requirements are that the source being measured have sufficient harmonic output so that harmonics fall within the fundamental, that is 20 - 40 mc., range of the instrument. This requirement can readily be met by most transmitters and if it cannot be met, harmonics can be generated by means of a diode type distortion device. The method of operation is identical with the method of measuring a frequency within the range of the instrument. However, when the final frequency measurement has been made, the dial readings must be divided by the order of the harmonic being measured. For example, if the transmitter being measured has a fundamental frequency of 7.215 mc. the measurement can be made at the third harmonic, which would be 21.645 mc. When this reading of 21.645 mc. has been obtained, it must be divided by 3 to obtain the transmitter frequency. The same accuracy is maintained as in the normal operating range of the instrument.

7. AUXILIARY OUTPUT.

In addition to the normal output of the Frequency Meter, that is, 20 - 1000 mc., there also is available the output from the low frequency variable oscillator, 1 to 2 mc., its harmonics, and the 1 mc. crystal oscillator and its harmonics.

These outputs are obtained by placing the Function Switch in the CAL position and connecting to the auxiliary output jack. The source impedance of the auxiliary output is 24 mmfs.

In order to utilize the frequencies which are available it must be kept in mind that both the crystal oscillator and its harmonics, and the low frequency oscillator and its harmonics are present at all times, and that beats between various frequencies can occur, therefore great care must be used in utilizing these outputs. For example: in calibrating the instrument to WWV the procedure outlined in Section IV, Maintenance, paragraphs 1A and 1B, should be followed. This same procedure applies when any harmonic from the 1 mc. crystal oscillator is desired.

When output from the 1 - 2 mc. low frequency oscillator or its harmonics is desired it must be remembered that the 1 mc. crystal oscillator and its harmonics are always present, but are fixed in frequency and can be differentiated from the low frequency oscillator signals by varying the low frequency oscillator.

The prime purpose for the auxiliary output is to provide suitable coupling to the 1 mc. crystal oscillator in order to calibrate the crystal against WWV or any primary standard. Any other uses of those frequencies which are available depends entirely upon the ability of the operator to separate the wanted signals from the unwanted.

It should always be kept in mind that the actual frequency of the low frequency oscillator is 2 mc. minus the dial readings.

8. METHOD OF DETERMINING THE FREQUENCY OF AN ENTIRELY UNKNOWN SOURCE.

A. Frequencies Known to be Above 20 Megacycles.

The method to be described requires only that the source be known to be above 20 mc. Procedure is as follows:

(1) Using the standard measuring procedure and starting at 20 mc. with the search oscillator, tune the search oscillator through the entire range and pick out the first strongest beat note against the unknown signal. Measure this frequency very carefully and call it f_1.

(2) Continue tuning upwards in frequency with the search oscillator until the next response having the beat note of approximately the same intensity is found. Measure this frequency and call it f_2. If only one response has been found of high signal intensity, then the frequency being measured is in the fundamental range of the instrument, that is 20 to 40 megacycles (or 40 to 60 mc. on second harmonic if beat note falls between 20 and 30 mc). These two cases may be distinguished by the fact that the beat note changes frequency twice as fast as the tuning of the low frequency oscillator if the response is on second harmonic.

(3) If two responses have been found then it is obvious that the first response occurs at a frequency $nf_1 = x$ where n is some integer representing the harmonic being used and x is the unknown frequency, and similarly, since the Frequency Meter was tuned upwards in frequency to the next harmonic response, this response would occur at $(n-1)f_2 = x$ where n-1 indicates that the next lower harmonic of the Frequency Meter was being used when f_2 was measured. Solving these equations for n we obtain $n = \frac{f_2}{f_2 - f_1}$. Having substituted the actual measurements into this equation, n will come out to be very close to some integral value. Choosing the closest integral value for n the unknown frequency is then this integer times f_1 or $x = Nf$ where N is the closest integral value to the n calculated by the equation above.

B. Frequencies Known to be Below 20 Megacycles.

(1) Starting at 20 mc., tune the search oscillator throughout its range and select the first loudest response. Measure this frequency carefully and call it f_1.

(2) Continue tuning upwards in frequency until the next response of approximately the same intensity has been obtained. Measure this and call it f_2. If no second response can be obtained, then the response is a second harmonic response and the frequency of the unknown would be $\frac{f_1}{2}$.

(3) If a second response was obtained, then it is obvious that the first response was obtained at a frequency $nx = f_1$, where n is an integer representing the harmonic of the source that was used in the measurement of f_1 and similarly, the second response would occur at $(n+1)\ x = f_2$ indicating that the next higher harmonic of the source was used in the second measurement. Solving these equations for n we obtain $n = \frac{f_1}{f_2 - f_1}$. Substituting the actual measurements into this equation, n will come out to be very close to some integral value. Choosing the closest integral value to the n obtained and substituting into the equation above, we obtain $x = f_{1/N}$ where N is the integral value obtained above.

SECTION III
THEORY OF OPERATION

1. GENERAL.

The FM-3 is a heterodyne type frequency meter in which frequencies are measured by heterodyning two signals together in a detector and adjusting them for zero difference in frequency as indicated by the difference frequency heterodyne beat note. The fundamental range of the instrument is 20 through 40 mc. Harmonics through the 25th are used for complete coverage throughout the range from 20 to 1000 mc.

The basic principle of operation is the interpolation between accurately known crystal harmonic frequencies by means of a low frequency calibrated oscillator. Figure 4 is a block diagram of the overall system. Referring to Figure 4 the crystal standard from which all measurements are referred and from which the harmonics are derived is a 1 mc. oscillator, V_{6A}. This oscillator is fed to a two stage tuned harmonic amplifier consisting of V_{6B} and V_7. The tuned circuits are tuned by means of the MC selector knob and the dial is calibrated in mc. An AGC loop is formed around the second stage of this amplifier and its cathode current actuates the meter on the front panel. The selected harmonic is fed to the carrier input of a balanced modulator Y_5 through Y_8. The modulation for this balanced

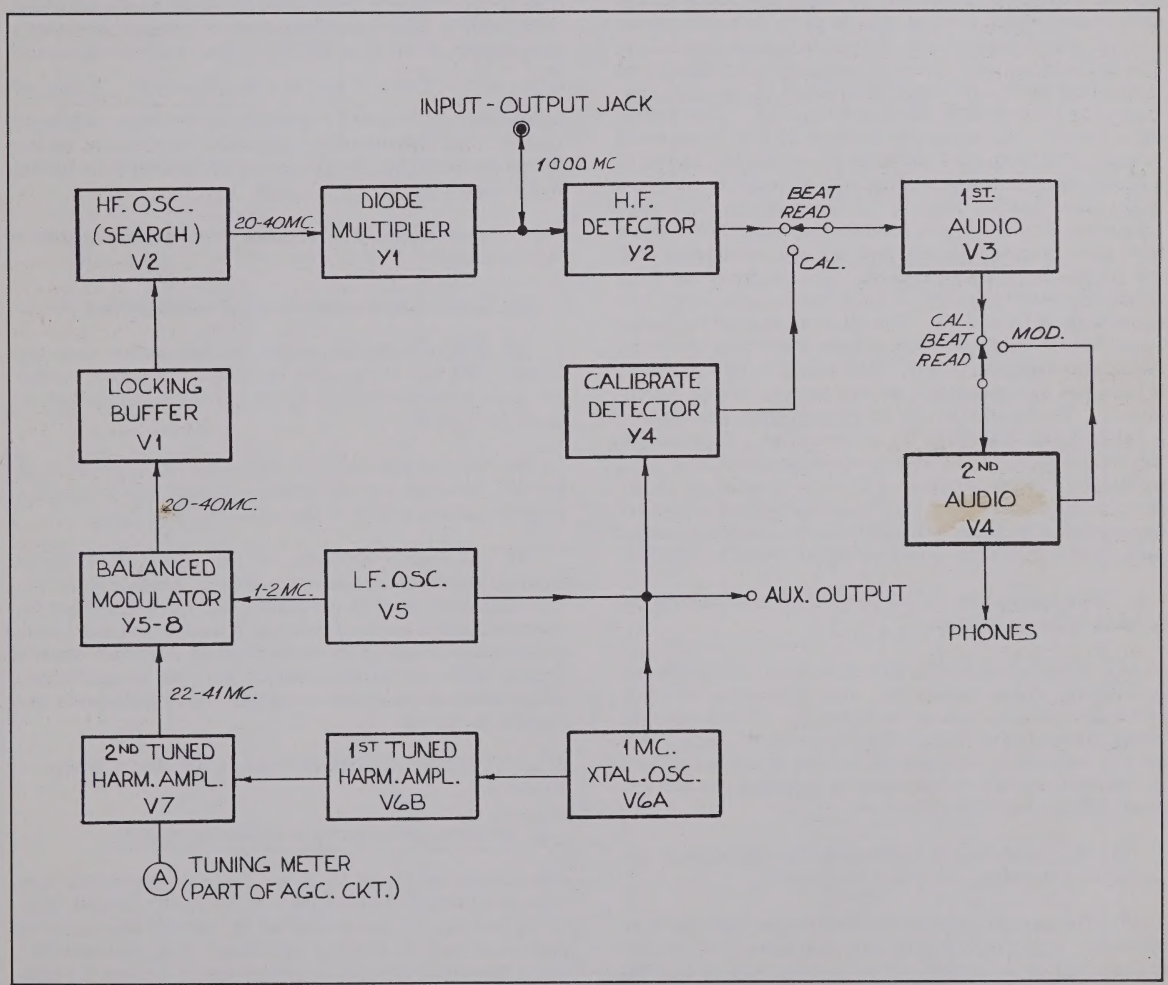

Figure 4. FM-3 Block Diagram

modulator is derived from the low frequency oscillator V_5. This oscillator covers a 1 to 2 mc. range and the frequency is controlled by the LF oscillator knob (C) and its frequency is 2.000 mc. minus the right hand dial readings. The low frequency oscillator signal modulates the selected crystal harmonic in the balanced modulator and the output difference frequency is fed to the locking buffer V_1. In this manner the difference frequency from the balanced modulator can be made to cover a 1 mc. range between any of the selected crystal harmonics and therefore the difference frequency can become continuous over any range desired. In the particular case of the FM-3 the crystal harmonic multipliers are tuned from the 22nd through the 41st harmonic of the 1 mc. crystal. Therefore, the difference frequency output from the balanced modulator covers the range of 20 through 40 mc., the same as the fundamental range of the Frequency Meter. The locking buffer amplifies this difference frequency and feeds it to the high frequency search oscillator V_2. If the search oscillator is tuned to the same frequency as the difference frequency, it will lock to this difference frequency and behave then essentially as an amplifier. The high frequency search oscillator frequency is controlled by the HF oscillator knob (A) and its frequency is indicated by the left hand dial. This oscillator covers the same 20 through 40 mc. frequency range. The output of the search oscillator is fed to a diode type harmonic multiplier, Y_1, and from there to the input-output jack of the instrument. The high frequency detector Y_2 is used to obtain the heterodyne beat note between the locked search oscillator and the frequency being measured. The output of the high frequency detector is fed to a two stage audio amplifier consisting of V_3 and V_4. The second stage of the audio amplifier is arranged with a feed-back loop so it can become an audio oscillator. When used in this function, it becomes the modulation source for the search oscillator. To calibrate the low frequency oscillator, a calibration detector, Y_4 is included. This allows the correction of the low frequency oscillator frequency to its dial readings. The low frequency oscillator output and the 1 mc. crystal output and their harmonics are made available at the auxiliary output jack in the calibrate position of the Function Switch.

A. The operation of the circuit in measuring the frequency is as follows:

(1) All circuits with the exception of the search oscillator, diode multiplier, high frequency detector and audio stages, are made inactive. The frequency being measured is fed to the input-output jack. The search oscillator fundamental or one of its harmonics is then matched to this frequency by means of the heterodyne difference frequency.

(2) The remaining circuits with the exception of the calibration detector, are then activated.

(3) The proper crystal harmonic (that one which is between 1 and 2 mc. higher than the search oscillator frequency) is selected. The calibration on the MC selector dial is arranged so that when the number in the window agrees with the MC portion of the high frequency search oscillator dial the proper harmonic will be selected.

(4) The low frequency oscillator is then tuned throughout its range until the difference frequency from the balanced modulator approaches very close to the high frequency search oscillator frequency. When this occurs the search oscillator is pulled away from the frequency being measured and this accounts for the change in beat note frequency. If the low frequency oscillator tuning is continued, eventually the search oscillator locks to the difference frequency and behaves essentially as an amplifier. Tuning of the low frequency oscillator is now continued until the locked search oscillator frequency or one of its harmonics again exactly matches the frequency being measured. The frequency is then read from the dials on the instrument.

(5) Calibration. All circuits with the exception of the high frequency search oscillator and the high frequency detector are active and the output from the calibration detector is now fed to the audio stages. The low frequency oscillator is tuned to a corrected dial reading where the frequency of the low frequency oscillator should be an improper rational fraction $\frac{P}{Q} \times 1$ mc. where P and Q are integers. Zeros of heterodyne beat note frequency should occur at these points. By means of a trimmer, controlled by the calibrate knob (D), the frequency is corrected by tuning for a zero beat.

B. In measuring the frequency the above procedure is reversed.

(1) Calibration as previously described takes place.

(2) With all circuits except the calibration detector active, the low frequency oscillator is tuned so that its dials read the fractional part of the desired instrument frequency.

(3) The proper crystal harmonic is selected with the MC selector and the desired instrument frequency appears at the output of the balanced modulator.

(4) The search oscillator is then tuned until it locks to this instrument frequency. This is evidenced by the locking signal heard in the phones and the desired output frequency is now available at the input-output jack. If modulated output is desired, the Function Switch is placed in the MOD position and the second audio stage becomes an audio oscillator which modulates the search oscillator.

2. DETAILED CIRCUIT DESCRIPTION. Refer to figure 5.

A. Search Oscillator and Diode Multiplier.

The search oscillator V_2 is an electron coupled Hartley type oscillator obtaining its bias from the combination of R_3 and C_6. A small amount of cathode bias to limit plate current is obtained by virtue of R_4 bypassed by C_7. The tuned circuit is comprised of L_7 and C_4 with a trimming capacitor C_5. The plate circuit of the oscillator consists of a choke L_2, which is resonant roughly to the geometrical center of the band, and the diode multiplier Y_1, and R_6, a 47 ohm resistor to

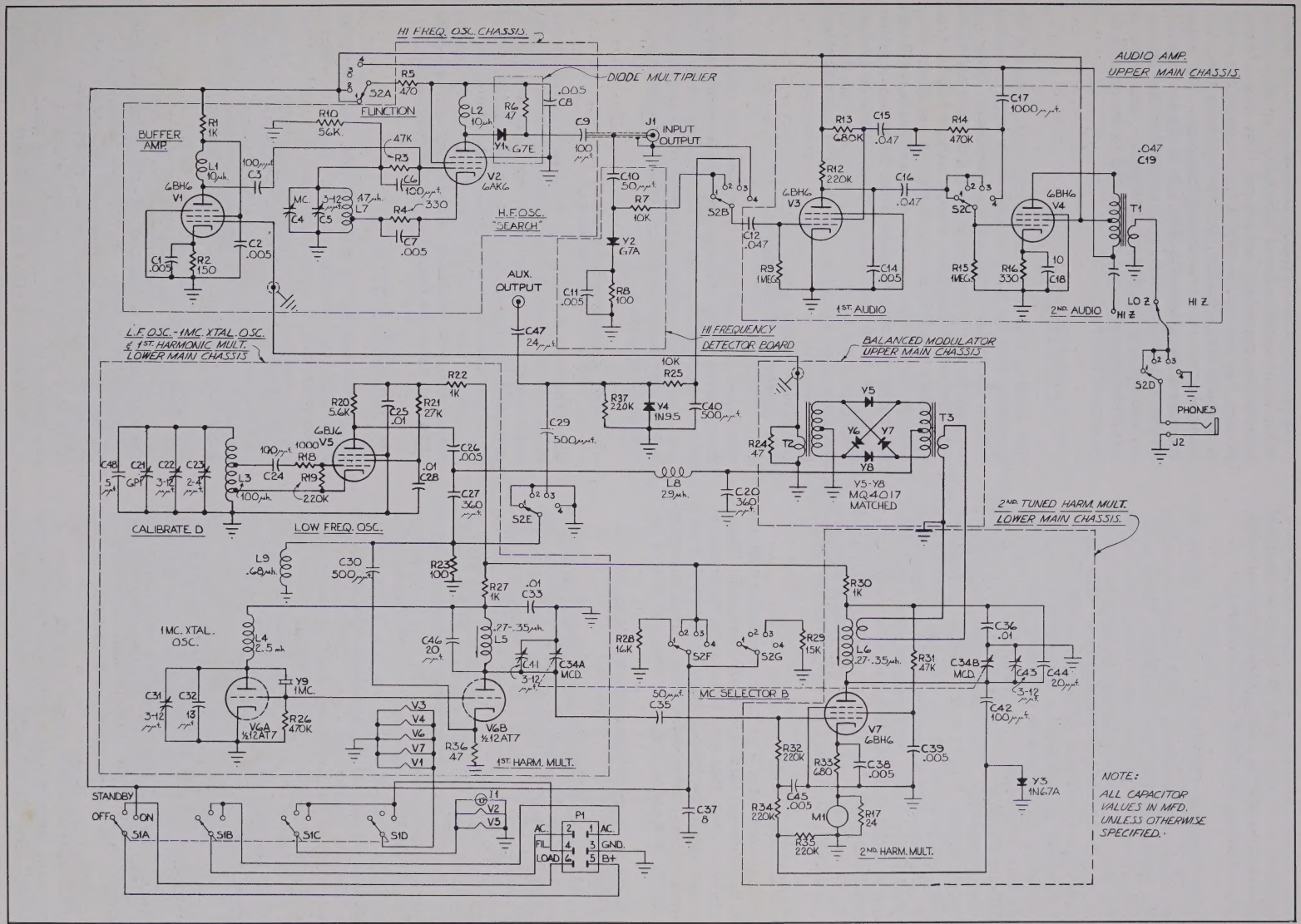

Figure 5. FM-3 Schematic Diagram

match the transmission line to the input-output jack. The waveform at the plate of V_2 is clipped by the diode multiplier and results in a waveform that is very rich in harmonics being fed out of the instrument.

B. Low Frequency Oscillator.

The low frequency oscillator V_5 is another modified electron coupled Hartley type oscillator. Bias is obtained by virtue of C_{24} and R_{19}. The grid is tapped halfway down on the coil L_3 to reduce tube loading effects by a factor of approximately 4. The tuning capacitor C_{21} is a specially designed straight line frequency variable which has been temperature compensated to match the particular coil being used. There are two trimmer capacitors, C_{22} and C_{23}. C_{23} is the calibrate trimmer and C_{22} is used to set the minimum circuit capacity. The output in the plate circuit is coupled through C_{26} to a constant K. pi type low pass filter consisting of C_{27}, L_8 and C_{20}. This serves to filter out undesired harmonics of the low frequency oscillator above 2 mc. which would cause spurious modulation products in the balanced modulator. For calibration purposes, the input leg of the filter C_{27} is lifted by 100 ohms R_{23} and coupled to the calibration detector along with the output from the crystal oscillator.

C. Crystal Oscillator.

The crystal oscillator V_{6A} is an oscillator with the crystal Y_9 connected between the plate and grid. There is a trimmer capacitor C_{31} from plate to ground to enable exact adjustment of the crystal frequency to 1 mc. The output which is used to drive the crystal harmonic multipliers is coupled directly from the grid of V_6.

D. First and Second Tuned Crystal Harmonic Amplifiers.

The tuned crystal harmonic amplifiers V_{6B} and V_7 are gang tuned by C_{34A} and B. The first stage, V_{6B} obtains its drive and bias directly from the grid of the crystal oscillator. A small amount of crystal signal is taken from the cathode across R_{36} and coupled through C_{30} for calibration purposes. The plate is parallel tuned by virtue of L_5 and C_{34A} with trimmers C_{41} and 46. The output from the first stage is coupled through C_{35} to the grid of V_7. V_7 is a pentode type class A RF amplifier with tuned circuit consisting of L_6 and C_{34B} trimmed by C_{43} and C_{44}. The voltage appearing at the plate of V_7 is coupled to the shunt type diode detector Y_3 through C_{42}. The output of this detector which is filtered by R_{34} and C_{45} is a negative voltage whose amplitude is approximately proportional to the amplitude of the selected crystal harmonic appearing at the plate of V_7. This negative voltage is used as grid bias for V_7 and so tends to maintain the amplitude of the harmonics constant over the frequency range. The cathode current of V_7 passes through M_1 and when the harmonic amplitude is a maximum, the negative grid bias is also a maximum therefore the current indication of this meter is a minimum. The output is link coupled from L_6 to the input of the balanced modulator.

E. Balanced Modulator.

The balanced modulator is a balanced ring diode type modulator. The carrier input is coupled through T_3, a transformer with a balanced secondary. The modulation input is fed between the center tap of the input transformer secondary and ground. The output transformer has the center tap of its primary grounded. In the balanced modulator, the low frequency oscillator modulates the selected crystal harmonic. The output consists of the side bands only; that is the sum and difference frequencies between the selected crystal harmonic and the low frequency oscillator. The output is loaded by R_{24} 47 ohms, and is fed to the grid of the locking buffer V_1.

F. Locking Buffer.

The locking buffer V_1 is pentode type Class A RF amplifier with the tuned circuit of the high frequency search oscillator acting as its plate load. With this arrangement the locking buffer acts as a selective amplifier which amplifies a very narrow band of frequencies centered about the search oscillator frequency. When the search oscillator is tuned to the difference frequency coming from the balanced modulator, the difference frequency amplitude is greatly amplified at the plate of V_1 and serves to lock the high frequency search oscillator frequency to this difference frequency.

G. Input-Output Circuit.

The input-output circuit is essentially matched at frequencies above 100 mc. The input-output jack is coupled directly through 50 ohm coaxial cable to C9 and the diode multiplier resulting in a very efficient transmission path for high order harmonics of the search oscillator.

H. High Frequency Detector.

High frequency detector Y_2 is a shunt type diode detector having input capacity of approximately 2 mmf. and a fairly large input resistance. This results in negligible loading on the input-output circuit. Y_2 is doped germaniam diode suitable for VHF detection. C_{11} and R_8 are included to prevent an audio ground loop. R_7 is an isolating resistor to prevent cable capacities from loading down the detector input.

I. Calibration Detector.

Calibration detector Y_4 is a shunt type diode detector. R_{25} is again an isolation resistor. C_{40} is included to improve the audio frequency response of the system for low frequencies. The input to the detector is also coupled through C_{47}, 24 mmf., to the auxiliary output jack and makes available the low frequency oscillator frequency and the crystal frequency and their harmonics in the CAL position of the Function Switch.

J. Audio Amplifier.

The audio amplifier is a two stage high gain frequency compensated amplifier. V_3 the input stage is a semi-starved pentode with the frequency correction network R_{11} and C_{14} in its plate circuit. The output of V_3 is fed to V_4 a pentode output amplifier which has the output transformer in its plate circuit. Either high impedance or low impedance output may be obtained. For crystal

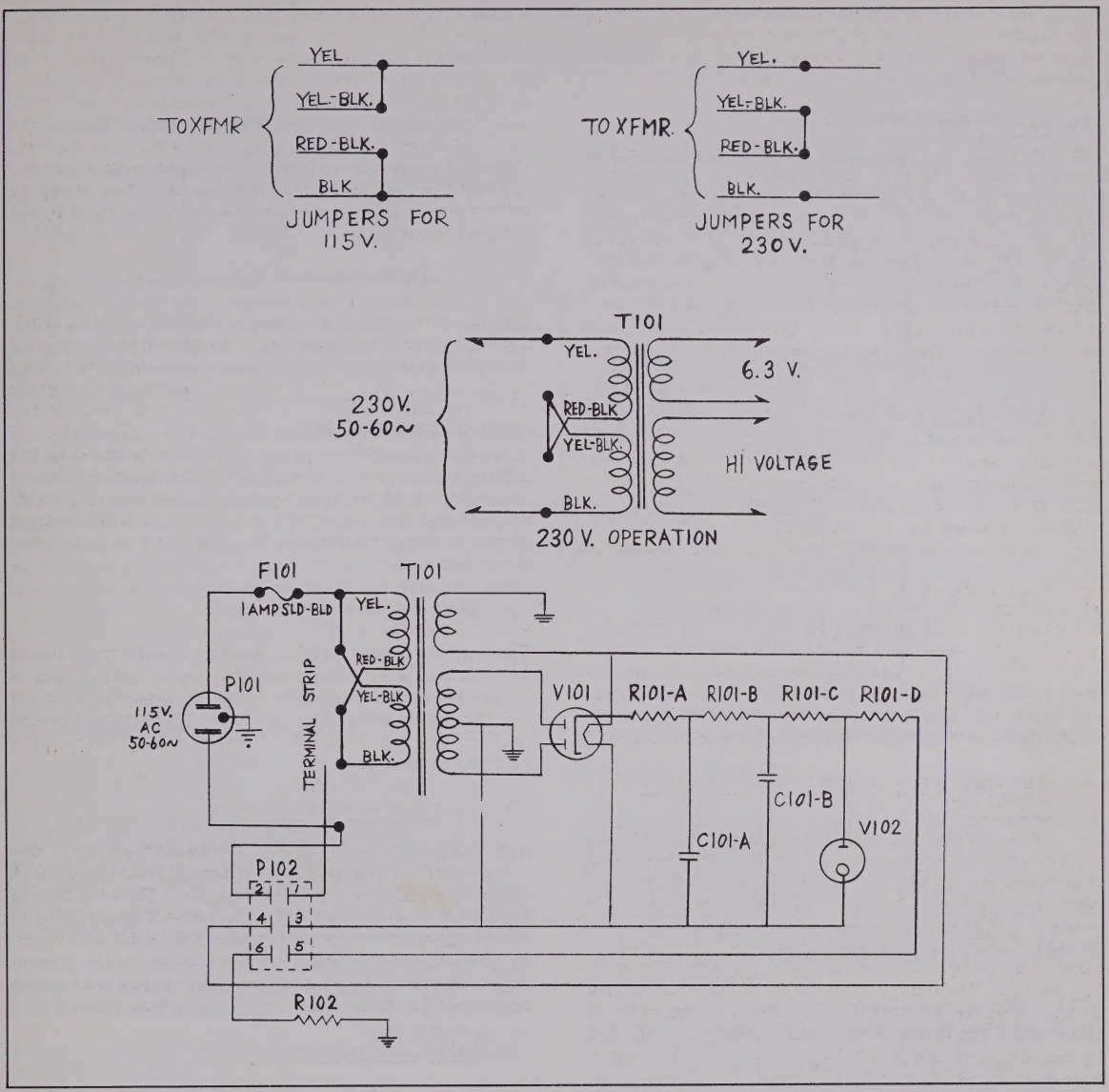

Figure 6. PS-3 Schematic Diagram

phones the high impedance output is obtained by coupling the phones through C_{19} to the plate of V_4. Low impedance output is obtained from the secondary of the output transformer. IT IS RECOMMENDED THAT WHENEVER MAGNETIC HEAD PHONES ARE USED, THAT LOW IMPEDANCE OUTPUT BE USED SINCE UNDESIRABLE LOW FREQUENCY RESONANCES MAY OCCUR IF THE HIGH IMPEDANCE OUTPUT CONNECTION IS USED. In the MOD position of the Function Switch the primary of the output transformer is coupled back to the grid of the second stage through C_{17} and so forms a blocking type audio oscillator. At the same time the search oscillator plate supply lead is switched to this feedback connection on the transformer and thus modulation is obtained.

K. Power Circuits.

Power to the Frequency Meter is controlled by S_1, the power switch. This is a switch having 3 positions, OFF, STAND BY and ON. Either the self-contained AC supply or the batteries are controlled by this switch. In the STAND BY position only the low frequency oscillator, V_5, and the high frequency oscillator, V_2, filaments are lit. In the ON position plate and filament power are supplied to all circuits depending upon the position of the Function Switch.

L. Power Supply. Refer to figure 6.

(1) PS-3. The PS-3 power supply is designed to work with the FM-3, and switching arrangements are

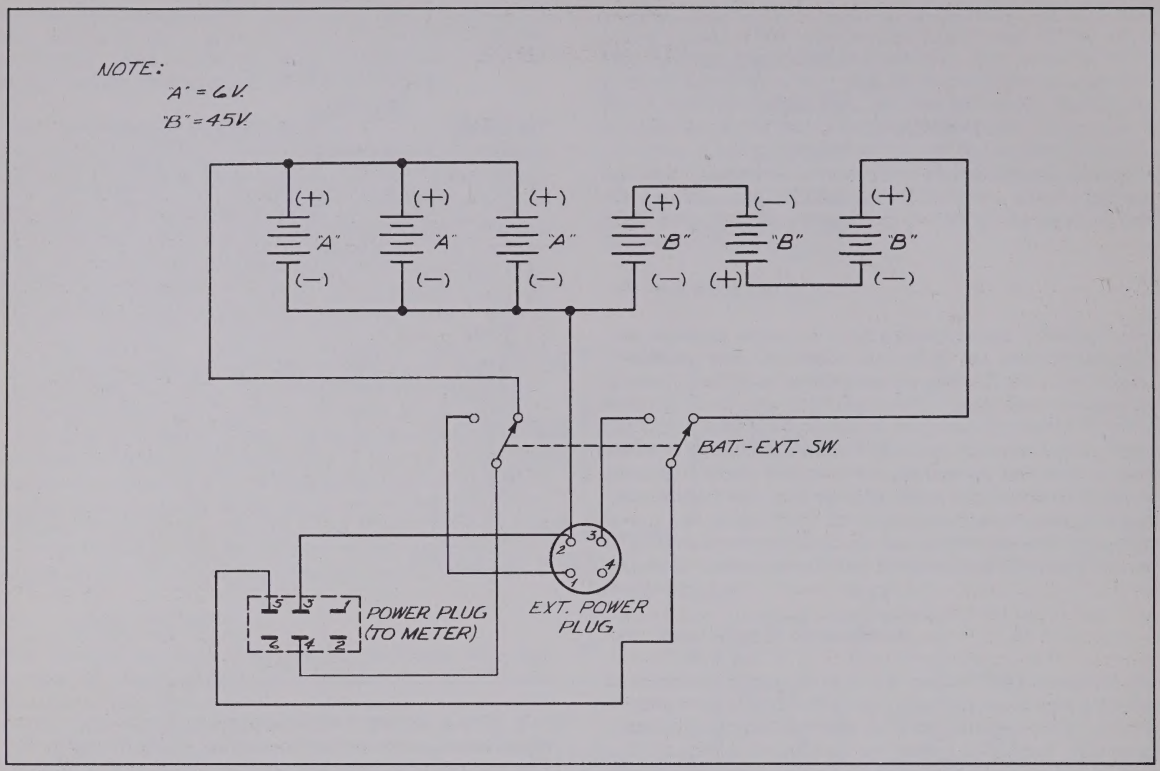

Figure 7. Schematic: Battery Power Supply

provided in the FM-3 to turn the power supply off and on. A dummy load is also included in the power supply so that when the instrument is in the STAND BY position the power supply is loaded to prevent damage to the voltage regulator tube. The PS-3 is designed to provide satisfactory performance over the input line voltage range of 105 and 125 volts.

(2) Batteries or External Power Supply. In the carrying case model with provisions for batteries, there is included a switch and plug which serve to enable the use of an external power supply or the batteries, depending upon the switch position selected. The requirements on the external power supply can best be met with a simple voltage regulator circuit shown in figure 8 and an AC filament supply 6.3 volts, 1.2 amps.

The FM-3R consists of a standard FM-3 instrument mounted in a 3/16, 19 inch standard 8-3/4 inch panel along with a PS-3.

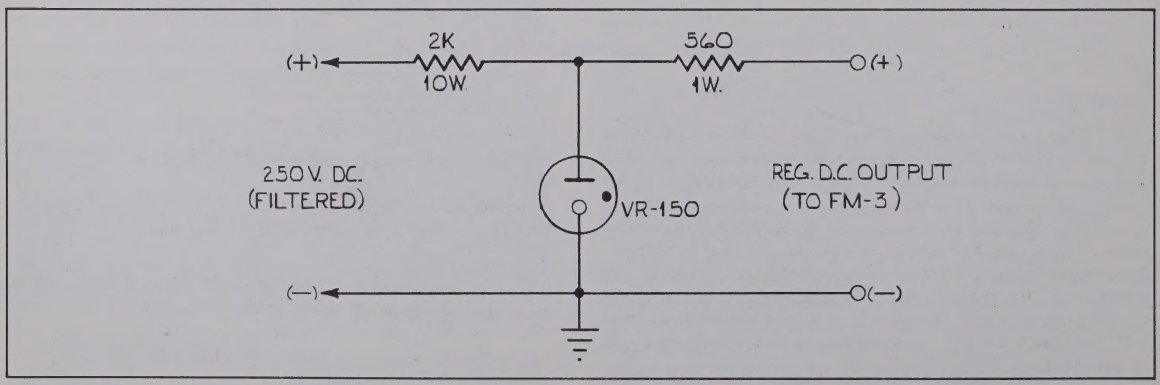

Figure 8. FM-3 Suggested 135V. Regulated Power Supply

SECTION IV
MAINTENANCE

1. ADJUSTMENT OF CRYSTAL OSCILLATOR.

If it becomes necessary to adjust the crystal oscillator for any reason the procedure is as follows: (The meter does not have to be removed from its case for this adjustment.)

A secondary standard whose frequency bears an integral relationship to 1 mc., accurate to at least 1 part in a million and a receiver capable of tuning to frequency in the range of 1 - 20 mc., are required for this adjustment. If WWV can be received the secondary standard will not be required.

A. Adjustment with the Secondary Standard. Allow one hour warm up period for the Frequency Meter in the CAL position of the Function Switch. Provide suitable coupling from secondary standard to the receiver and provide coupling from the auxiliary output jack to the receiver. Tune the receiver to a frequency at which harmonics of both the secondary standard and the 1 mc. crystal in the frequency meter exist. The receiver AVC should be off. Change tuning on the low frequency oscillator to make certain that it is not introducing a beat note also. Remove the plug button on the back of the carrying case and the crystal trimmer will be available through the hole. Carefully adjust the trimmer for zero beat against the secondary standard.

B. Adjustment with WWV. Tune the receiver to one of WWV's output frequencies, preferably the 15 to 20 mc. output frequency. The receiver AVC should be off. Again allow the Frequency Meter one hour warm up in the CAL position of the Function Switch. Provide suitable coupling between the auxiliary output jack and the receiver antenna. Check to make certain that the low frequency oscillator is not producing a beat note. Adjust the crystal for zero beat when WWV is unmodulated. Then when the modulation is on proceed for the fine adjustment to precise zero beat by the side tone method of zero beating.

2. ALIGNMENT OF TUNED CRYSTAL HARMONIC MULTIPLIER.

If it becomes necessary to align the tuned crystal harmonic multiplier, the procedure is as follows: (A receiver capable of tuning from 22 - 41 mc. is required.)

A. Place the Function Switch in the CAL position. Turn the MC selector dial all the way to the low frequency and until it stops. The bottom one-third of the 2 and the 0 should just be visible. If this is not the case the dial must be reset. To do this the dust cover must be removed and the set screws on the dial loosened. Then adjust the dial so that the bottom one-third of the numbers are visible and re-tighten the set screws making certain that the dial has been pushed well forward to provide spring tension on the wiper in front of the dial.

B. Tune the MC selector so that the 20 is exactly centered in the small window. Remove the top cover of the multiplier assembly and hang a wire from the receiver antenna terminal down into the front section of the multiplier can. Tune the receiver to 22 mc. Adjust the coils available through holes in the left side dust cover as viewed from the front for maximum response in the receiver. For final tuning use the meter on the front panel of the Frequency Meter and tune for the greatest dip.

C. Tune the MC selector so that the 39 is exactly centered in the window. Tune the receiver to 41 mc. and adjust the two trimmer capacitors next to the coils for maximum response in the receiver at 41 mc. For final tuning again use the meter.

D. Repeat steps B and C until no further alignment is necessary.

3. HIGH FREQUENCY OSCILLATOR ALIGNMENT.

If it becomes necessary to re-align the high frequency oscillator the procedure is as follows:

A. Place the instrument in the BEAT position. Feed an accurate source of 5 mc. that has high harmonic content to the input-output jack of the Frequency Meter.

B. Tune the high frequency oscillator to 20 mc. and zero beat against the 20 mc. harmonic of the 5 mc. source. Loosen the set screws on the dial and adjust the dial so that it reads exactly 20 mc.

C. Tune the high frequency oscillator so that its dial reads exactly 40 mc. and adjust the trimmer which is available through a hole in the bottom of the dust cover until zero beat against the 40 mc. harmonic of the source is reached.

D. Check other harmonics within a range of the high frequency oscillator, e.g., 25, 30 and 35 mc., to make certain that the 40 mc. harmonic was the one selected. If not, readjust the trimmer until this condition is reached.

E. Repeat steps B and C until no further adjustment is necessary.

4. LOW FREQUENCY OSCILLATOR ALIGNMENT.

If it becomes necessary to re-align the low frequency oscillator the procedure is as follows:

A. Place the instrument in the CAL position. Tune the low frequency oscillator so that its dial read exactly .000. Adjust the calibrate knob (D) for zero beat.

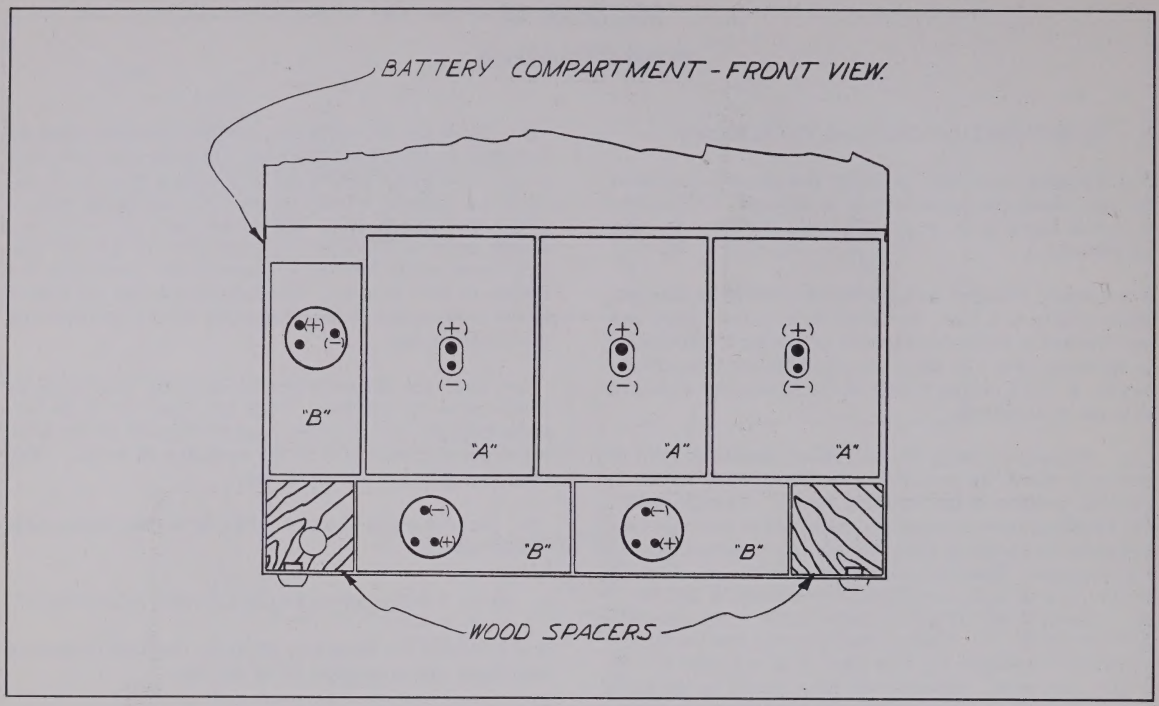

Figure 9. FM-3 Battery Location Diagram

B. Tune the low frequency oscillator to the largest calibration point as indicated on the correction chart. Adjust the coil (available through a hole in the side of dust cover) with a long insulated type tuning tool for zero beat.

C. Repeat steps A and B until no further adjustment is necessary.

D. Turn the calibration knob (D) so that its pointer lines up with the center mark. Re-tune the low frequency oscillator so its dial read .000 and adjust the trimmer capacitor available through a hole in the top of the dust cover for zero beat.

E. Check the calibration points between .000 and the largest calibration point and note the run-out from indicated readings. If the run-out is greater than 400 cycles at any point the low frequency oscillator must be re-calibrated.

5. RE-CALIBRATION OF THE LOW FREQUENCY OSCILLATOR.

A crystal controlled 10 kc. multivibrator is required to re-calibrate the low frequency oscillator. The procedure is as follows:

A. Allow the Frequency Meter one hour warm up period in the CAL position of the Function Switch.

B. Couple the output from the crystal controlled 10 kc. multivibrator to the auxiliary output jack on the Frequency Meter. Check to see if sufficient output is available for accurate zero beating at every 5 kc. interval of the low frequency oscillator dial. If this is not the case then a receiver covering the range of 2 - 4 mc. may be used in conjunction with the 10 kc. multivibrator. Couple the multivibrator and the auxiliary output jack to the receiver. The receiver should be tuned to the second harmonic of the low frequency oscillator.

C. Adjust the end points on the low frequency oscillator in the manner described under LOW FREQUENCY OSCILLATOR ALIGNMENT with the exception that the end points must both be set exactly, that is, .000 and 1.000.

D. Starting at the .000 end of the low frequency oscillator tuning range (receiver tuned to 4 mc.) simultaneously tune the receiver and low frequency oscillator in 5 kc. increments and precisely zero beat the low frequency oscillator, recording each dial reading at the zero beat condition. There will be a total of 201 such readings.

E. From this recorded data make a plot of low frequency oscillator error versus dial reading in a manner similar to the original chart. Select from the recorded data the same calibration points as were originally used with the Frequency Meter. The calibration points will of course not be identical but the recorded value is the one to be used. Calibration is now complete.

6. INSTALLATION OF BATTERIES.

A. Remove the battery compartment cover by means of two Dzus snap fasteners.

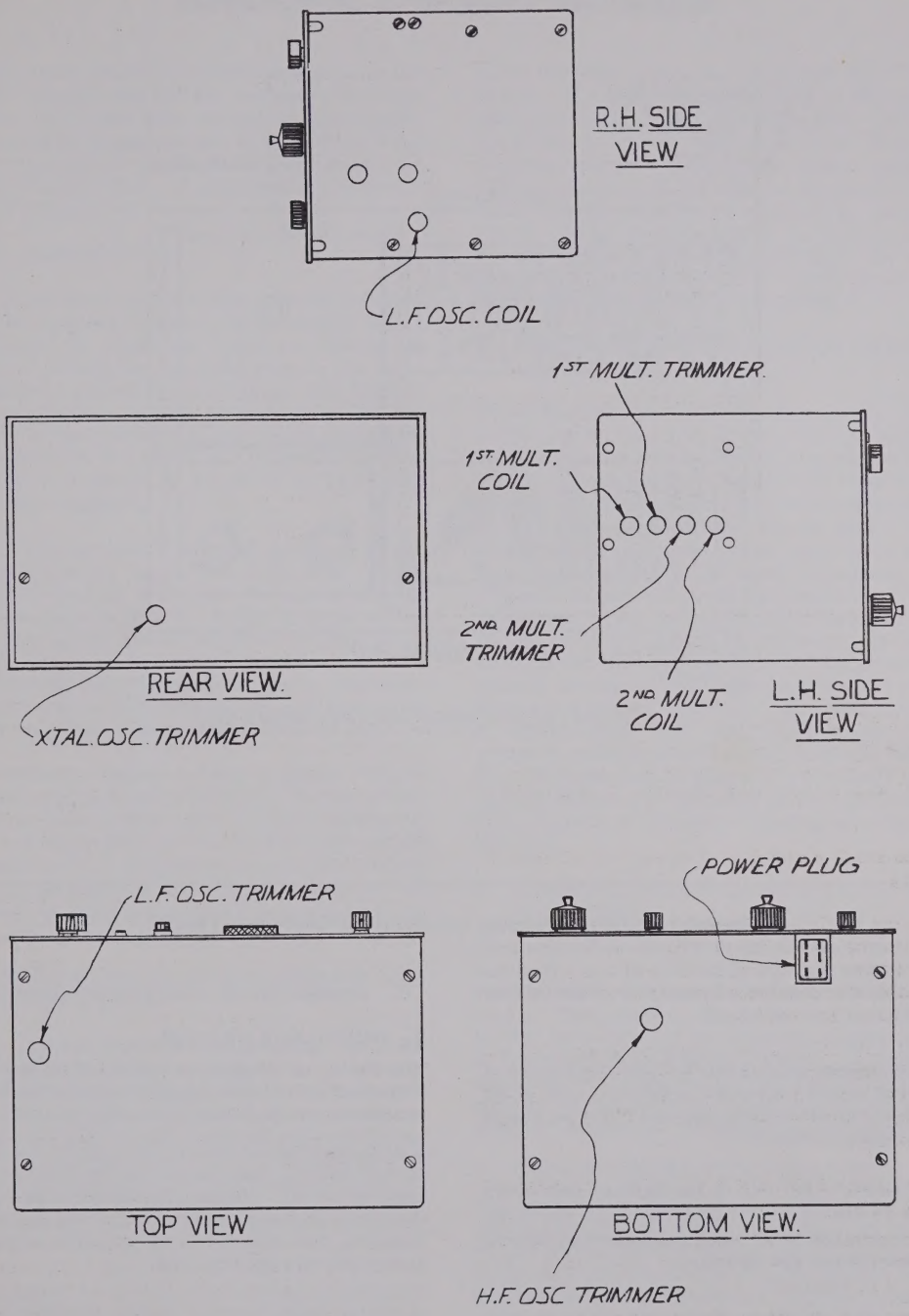

Figure 10. FM-3 Trimmer Location

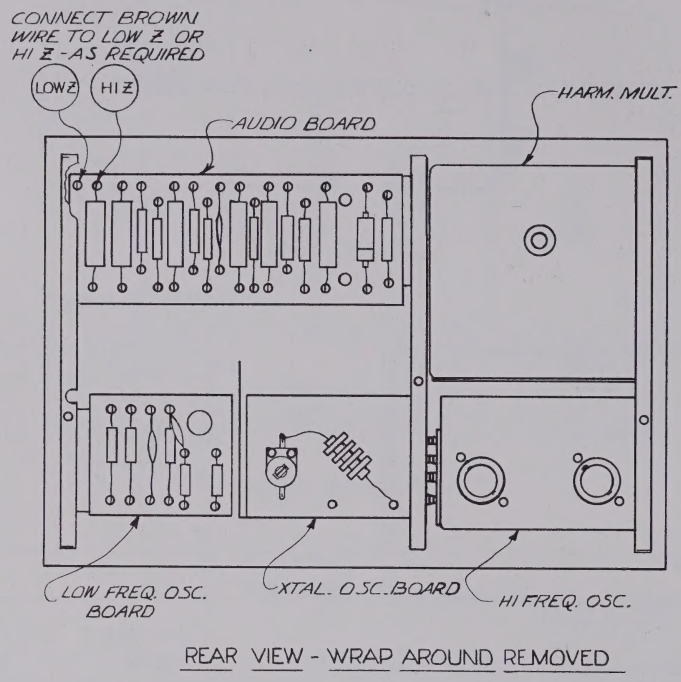
CONNECT BROWN WIRE TO LOW Z OR HI Z - AS REQUIRED
LOW Z
HI Z
AUDIO BOARD
HARM. MULT.
LOW FREQ. OSC. BOARD
XTAL. OSC. BOARD
HI FREQ. OSC.
REAR VIEW - WRAP AROUND REMOVED

Figure 11. FM-3 Terminal Locations for Impedance Change

B. Loosen the screw at the left hand side of the battery hold-down bar.

C. Lift the battery hold-down bar towards the top of the Frequency Meter as far as it will go. The other end of the battery hold-down bar may now be pulled from its retaining position.

D. Replace the right end of the battery hold-down bar into its retaining post. Slide the hold-down bar back to its normal position under the screw at the left hand side and tighten the screw.

E. Replace battery compartment cover.

7. IMPEDANCE CHANGE.

The FM-3, as shipped, is connected for low impedance output so that it will handle satisfactorily magnetic headphones ranging from 600 to 2000 ohms in impedance.

If high impedance operation for crystal headphones is desired, the impedance may be changed as follows (see figure 11). Remove the brown wire from the end terminal on the resistor board, as indicated in the diagram, and transfer to the adjacent terminal. This is the only change required.

SECTION V
FUNCTIONAL CHECKOUT PROCEDURE

This procedure was written to enable personnel in the field who are responsible for the maintenance of the FM-3 to make functional tests on the instrument with a minimum of test equipment and to determine from these tests whether the instrument needs repair or alignment or re-calibration. A knowledge of the theory and circuitry is assumed.

1. CIRCUIT CHECKOUT.

A. Place instrument in operation. Place Function Switch in CAL position. Tune low frequency oscillator throughout its range and listen for beat notes. This procedure checks out the audio stages, the calibration detector, the crystal oscillator, and the low frequency oscillator, as well as indicating that the power supply is functioning. If beat notes can not be heard there must be trouble in one of these circuits. If trouble exists it should be localized by individual circuit tests and repaired.

B. Place Function Switch in READ position. Tune MC selector and watch tuning meter for dips. If the meter fails to deflect or show dips there is trouble in the tuned harmonic amplifier. If operation is satisfactory, go through the normal process for generating a frequency. If proper lock-in can be obtained it can be assumed that the high frequency oscillator, the lock-in buffer, the balanced modulator and the high frequency detector are functioning satisfactorily.

C. Place Function Switch in MOD position. Check for operation of the modulation oscillator by connecting head phones to input-output jack. A small amount of modulating voltage appears at this jack through output coupling capacitor C_9. Modulation can also be checked by listening to the output of the meter in a receiver. If the instrument is operating properly proceed with the following calibration and alignment tests.

2. LOW FREQUENCY OSCILLATOR ALIGNMENT AND CALIBRATION CHECK.

A. Place Function Switch in CAL position. Set LFO to .000 and adjust calibrate control for zero beat. Tune LFO to 1.000 and zero beat carefully without disturbing the calibrate control and compare with the listed calibration point on the low frequency oscillator dial readings correction chart. If the discrepancy is more than 200 cycles the oscillator should be aligned. The procedure for this alignment is given in the FM-3 Instruction Manual in Section IV, Maintenance, paragraph 4.

B. If the alignment is satisfactory the calibration should now be checked. Set the LFO to .000 and adjust the calibrate control for zero beat. Check each calibration point between .000 and the largest point and compare the position of each zero beat with the points listed on the correction chart. If the discrepancy is more than 400 cycles the oscillator must be re-calibrated. If a more sensitive check is desired, set the oscillator to each listed calibration point, zero beat with the calibrate control, then move 50 kc. away in either direction and tune to zero beat without disturbing the calibration control. Compare the positions of these 50 kc. points with those called out by the correction curve. If the discrepancy is more than 150 cycles, the oscillator must be re-calibrated. Re-calibration procedure is given in the FM-3 Instruction Manual in Section IV, Maintenance, paragraph 5.

3. HIGH FREQUENCY OSCILLATOR TRACKING AND ALIGNMENT.

Place Function Switch in READ position. Set LFO to 1.000 and MC selector to 28. This procedure gives output from the balanced modulator at integral megacycles due to leakage, imperfect selectivity in the tuned harmonic amplifier, and cross modulation effects in the balanced modulator. The net result is that beat notes will be obtained every megacycle as the high frequency oscillator is tuned throughout its range. Compare the position of the zero beats with the calibration marks on the dial. If the discrepancy is more than two line widths alignment is necessary. If the error is so large that it is impossible to tell the frequency to the nearest megacycle, the alignment procedure given in the Instruction Manual, Section IV, Maintenance, paragraph 3, should be followed. Any small errors can be corrected by bending the end plates on the variable capacitor. When bending the plates it is necessary to align the end points first and then start at the high frequency end and progress to the low frequency end with the plate bending.

4. HARMONIC MULTIPLIER TRACKING AND ALIGNMENT.

Place Function Switch in READ position. Tune MC selector for dip on tuning meter every megacycle. Note position of numbers in window for each megacycle. The numbers should be well enough centered so that no portion of the adjacent numbers is visible at the point of minimum current. If this is not the case the harmonic multiplier should be aligned according to the procedure outlined in the Instruction Manual, Section IV, Maintenance, paragraph 2.

5. CRYSTAL OSCILLATOR FREQUENCY.

The crystal oscillator frequency should be checked by comparison with a suitable frequency standard. This can be accomplished by placing the Function Switch in the CAL position and feeding the crystal signal from the auxiliary output jack to a receiver along with the output from the frequency standard. The crystal frequency may be corrected by adjusting the trimmer available through the back of the instrument. This procedure is described in the Instruction Manual, Section IV, Maintenance, paragraph 1.

6. ADDITIONAL CHECKS.

A. Sensitivity. The sensitivity may be checked by feeding signals of the desired frequency to the instrument from a signal generator with an output of 1 millivolt. No difficulty should be experienced in locating the signals and obtaining good beat notes. This procedure will check out the diode multiplier and the high frequency detector.

B. Microphonics. The instrument may be checked for microphonics by placing the Function Switch in the READ position and tapping the panel or dust cover (with no beat notes present) and listening for excessive microphonics. Individual tubes and components may also be checked.

C. Low frequency oscillator stability may be checked by placing the Function Switch in the CAL position, obtaining a beat note at .000 and tapping the panel or dust cover and looking for excessive frequency shift. Frequency shift may be caused by a bad tube, bad connection in the tuned circuit or associated circuit of the tube, or a poor contact at the wiper on the variable capacitor, or something mechanically loose on the capacitor or gear train. Extreme care should be exercised in any operation concerning the variable capacitor so that the calibration will not be changed.

SECTION VI
PARTS LIST

Symbol	Description	Manufacturer or Type
R1	1K, 1/2W, 10%	AB
R2	150 ohm, 1/2W, 10%	AB
R3	47K, 1/2W, 10%	AB
R4	330 ohm, 1/2W, 10%	AB
R5	470 ohm, 1/2W, 10%	AB
R6	47 ohm, 1/2W, 10%	AB
R7	10K, 1/2W, 10%	AB
R8	100 ohm, 1/2W, 10%	AB
R9	1 Meg., 1/2W, 10%	AB
R10	56K, 1/2W, 10%	AB
R12	220K, 1/2W, 10%	AB
R13	680K, 1/2W, 10%	AB
R14	470K, 1/2W, 10%	AB
R15	1 Meg., 1/2W, 10%	AB
R16	330 ohm, 1/2W, 10%	AB
R17	24 ohm, 1/2W, 5%	AB
R18	1000 ohm, 1/2W, 10%	AB
R19	220K, 1/2W, 10%	AB
R20	5.6K, 1/2W, 10%	AB
R21	27K, 1/2W, 10%	AB
R22	1K, 1/2W, 10%	AB
R23	100 ohm, 1/2W, 10%	AB
R24	47 ohm, 1/2W, 10%	AB
R25	10K, 1/2W, 10%	AB
R26	470K, 1/2W, 10%	AB
R27	1K, 1/2W, 10%	AB
R28	16K, 2W, 5%	AB
R29	15K, 2W, 5%	AB
R30	1K, 1/2W, 10%	AB
R31	47K, 1/2W, 10%	AB
R32	220K, 1/2W, 10%	AB
R33	680 ohm, 1/2W, 10%	AB
R34	220K, 1/2W, 10%	AB
R35	220K, 1/2W, 10%	AB
R36	47 ohm, 1/2W, 10%	AB
R37	220K, 1/2W, 10%	AB
C1	.005 mf. disc	Erie 811
C2	.005 mf. disc	Erie 811
C3	100 mmf. tub. ceramicon	Erie GP1K±20%
C4	Variable Capacitor 140 mmf. Max.	Hammerlund MC-140-M
C5	Ceramic Trimmer 3-12 mmf. NPO	Erie TS2A
C6	100 mmf. tub. ceramicon	Erie GP1K±20%
C7	.005 mf. disc	Erie 811
C8	.005 mf. disc	Erie 811
C9	100 mmf. tub. ceramicon	Erie GP1K±20%
C10	50 mmf. tub. ceramicon	Erie GP1K±20%
C11	.005 mf. disc	Erie 811
C12	.047 mfd., 200V. paper	Goodall, type M503
C14	.005 mf. disc	Erie 811
C15	.047 mfd., 200V. paper	Goodall, type M503
C16	.047 mfd., 200 V. paper	Goodall, type M503
C17	1000 mmf. tub. ceramicon	Erie GP2L±20%
C18	10 mfd. 25 WV Electrolytic	Cornell-Dubilier BBR 10-25
C19	.047 mfd., 200V. paper	Goodall, type M503
C20	360 mmf. ±36 mmf. tub. ceramicon	Erie GP2K
C21	GPISLF Variable	Gertsch Prod., Inc.
C22	Ceramic Trimmer 3-12 mmf. NPO	Erie TS2A
C23	Air trimmer 2.4-4.2 mmf.	Sarkes-Tarzian H4Q
C24	110 silver mica	CM15E111J
C25	.01 mfd. disc	Erie 811
C26	.005 mf. disc	Erie 811
C27	360 mmf. ±36 mmf. tub. ceramicon	Erie GP2K
C28	.01 mfd. disc	Erie 811
C29	500 mmf. ±100 mmf.	Erie GP2K
C30	500 mmf. tub. ceramicon ±100	Erie GP2K
C31	Ceramic trimmer 3-12 mmf. NPO	Erie TS2A
C32	13 mmf. NPO tub. ceramicon ±10%	Erie NPOK
C33	.01 mfd. disc	Erie 811
C34 a, b	Variable Capacitor	Hammerlund MCD-140-M
C35	50 mmf. tub. ceramicon	Erie GP1K±20%
C36	.01 mfd. disc.	Erie 811
C37	8 mfd. 450 WV Electrolytic	Cornell-Dubilier BR 845-A
C38	.005 mfd. disc.	Erie 811
C39	.005 mfd. disc.	Erie 811
C40	500 mmf. ±100 mmf.	Erie GP2K
C41	Ceramic Trimmer 3-12 mmf. NPO	Erie TS2A
C42	100 mmf. tub. ceramicon ±20%	Erie GP1K
C43	Ceramic Trimmer 3-12 mmf. NPO	Erie TS2A
C44	20 mmf. ±2 mmf. NPO	Erie NPOK
C45	.005 mfd. disc.	Erie 811
C46	20 mmf. ±2 NPO	Erie NPOK
C47	24 mmf. ±2.4 mmf.	Erie GP1K
C48	5 mmf. N750K	Erie N750K
T1	Output Transformer	Triad 2426
T2	Bal. Mod. Output Transformer Assembly	TR-7-1
T3	Bal. Mod. Input Transformer Assembly	TR-7-2
S1	Power Switch	Oak #52897-F1
S2	Function Switch	Oak #52898-F4

Symbol	Description	Manufacturer or Type
S4 (FM-3 only)	DPDT Bat Handle Toggle Switch	H H Smith #513
J1	Input-Output Jack	Amphenol UG657/U
J2	Phone Jack	Switchcraft #11
J3	Aux. -Output	ICA 528B
P1	Power Plug	Jones #P306AB
P2 (FM-3 only)	Power Plug	S306FHE
P3 (FM-3 only)	Ext. Power Plug and mate	91-MC4F1 and 91-PC4M Amphenol
Y1	Germanium Diode	GE #G7E
Y2	Germanium Diode	GE #G7A
Y3	Germanium Diode	H. A. C. IN67A
Y4	Germanium Diode	H. A. C. IN95
Y5) Y6) Y7) Y8)	Special Matched Diodes	H. A. C. MQ-4017
Y9	1.000 MC Quartz crystal	GPI YC-1
M1	0-1 MA Meter	Int. Instr. #C-100
L1	10 uh Choke	Standard Coil XM401
L2	10 uh Choke	Standard Coil XM401
L3	LH Osc. Coil	GPI LR-3
L4	2.5 MH Choke	Standard Coil XM800
L5	1st stage Mult. Coil	LS-20
L6	2nd stage Mult. Coil	LS-21
L7	HF Osc. Coil	GPI LR-1
L8	29 uh Choke	GPI LF-1
L9	.68 uh Choke	GPI LA-1
V1	Locking Buffer Tube	6BH6
V2	HF Osc. Tube	6AK6
V3	1st Audio Tube	6BH6
V4	2nd Audio Tube	6BH6
V5	LH Osc. Tube	6BJ6
V6	Crystal Osc. and 1st Mult. Tube	12AT7
V7	2nd Mult. Tube	6BH6
BA1) (FM-3 only) BA2) (FM-3 only) BA3) (FM-3 only) BA4) (FM-3 only)	Filament Battery	Burgess 2F4 or equiv. (Not Supplied)
BA5) (FM-3 only) BA6) (FM-3 only)	Plate Battery	Burgess M30 or equiv. (Not Supplied)
I1	6.3 V. AC Miniature Lamp Bulb	Tung-Sol TS-51

PS-3 PARTS LIST

Symbol	Description	Manufacturer or Type
R101-A	1 K)	Sections of GPI Resistor Part No. RW-4
R101-B	1 K)	
R101-C	1250 ohm)	
R101-D	560 ohm)	
R102	Resistor, wire-wound, 4500 ohm, ±10%, 5 W	GPI RW-5
T101	Power Transformer	Triad 7854
P101	Power Receptacle	G. E. 2711
P102	Power Plug #S-306-FHE	Jones
V101	Rectifier Tube	6X5GT
V102	Voltage Regulator	OD3
F101	1 Amp. 4AG Fuse	Littlefuse
C101	10-10 mfd., 450 W.V. BRD-1145A	C.D.